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ABSTRACT

This minicourse was prepared for use with secondary physics students in the Dallas Independent School District and is one option in a physics program which provides for the selection of topics on the basis of student career needs and interests. This minicourse was aimed at providing students with a knowledge of the metric system and use of the slide rule. The minicourse was designed for independent student use with close teacher supervision and was developed as an ESEA Title III project. A rationale, behavioral objectives, student activities, and resource packages are included. Student activities and resource packages involve reading about the development of the metric system, defining the meter, using mass and time units, converting from one system to the other, measuring mass, length, and volume, and performing the basic slide rule operations. (GS)

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CAREER ORIENTED PRE-TECHNICAL PHYSICS

Metric System and Slide Rule

Minicourse

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1974

PRELIMINARY EDITION

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ESEA Title III Project

1974

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March 25, 1974

This Mini Course is a result of hard work, dedication, and a comprehensive program of testing and improvement by members of the staff, college professors, teachers, and others.

The Mini Course contains classroom activities designed for use in the regular teaching program in the Dallas Independent School District. Through Mini Course activities, students work independently with close teacher supervision and aid. This work is a fine example of the excellent efforts for which the Dallas Independent School District is known. May I commend all of those who had a part in designing, testing, and improving this Mini Course.

I commend it to your use.

Sincerely yours,

Nolan Estes

Nolan Estes
General Superintendent

mfs

CAREER ORIENTED PRE-TECHNICAL PHYSICS TITLE III ESEA PROJECT

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CAREER ORIENTED PRE-TECHNICAL PHYSICS

METRIC SYSTEM AND SLIDE RULE

MINICOURSE

RATIONALE (What this minicourse is about):

Every day of your life you are required to relate to a measurement of some kind. You may be asked to buy five (5) pounds of potatoes or to wait for ten (10) minutes. Your coach may require you to run the 100-yard dash. Each of the foregoing activities involves some common, standardized unit of measure. You have grown up using English units of measure. Very likely, you have accepted their existence and never wondered: "What is a yard?" "How much is a gallon?" "How long is a second?" Who decided on these units of measure?" "Is our English system of measure the one used mostly all over the world?"

Units of measure have a very long and colorful history, having been amongst the earliest "tools" invented by primitive man. Ancient Egyptians used the cubit, a measure about the length of the fore-arm, in the construction of the pyramids. The Romans used the pace as a measure for length. As trade, commerce, and construction flourished, man's need for a common system of measure increased. As international trade and travel developed, science and technology began to require more and more precise measurements. The need for a standardized set of units became inescapable. A standardized system needed to be defined scientifically, to be independent of changes in governments and to be identical for any geographic location.

Right after the French Revolution, the new French Republic designed and adopted the Metric System of Units. This convenient system was soon adopted by other nations and is used throughout most of the world today. Scientists of all countries use the metric system. But the English-speaking countries (primarily England, Australia, and the United States) adopted the English System of Units. Very recently, Australia and England have made progress in changing to the metric system. The United States has just begun to change over. During your lifetime you will see the English system disappear and be replaced by the metric system. You and your children will live in a metric world (Will you be able to help them with metric homework?).

The principal technical advantages of switching to metric measure in the United States include:

1) an expected increase in exports of manufactured goods, since metric countries prefer to purchase products made to metric measure. (If you have ever tried to repair a foreign car using English system tools, you know about this problem!)

2) anticipated money savings in the manufacture of complex machines in the United States, since many parts can be produced cheaper in certain metric countries

3) conservation of scarce materials, since a worldwide standard metric system reduces the need to manufacture excessive varieties and sizes of products. (For example, spark plugs, fasteners, nuts, bolts, and electric motors could be standardized.)

Are you aware that such technological giants as IBM, Caterpillar Tractor, International Harvester, General Electric, General Motors Corporation, and Ford Motor Company are already going metric? Ford Motor Company has a totally metric automobile engine plant in Ohio, to produce 2300 cc engines

for its Mustang II. The State of Ohio has begun the changeover by installing a dual system on some of its road signs. (For example, the following sign can be seen on one of Ohio's major highways: "Cincinnati--62 miles; 100 kilometers.") The California State Superintendent of Schools has initiated a plan to convert all public school mathematics texts exclusively to the metric system.

Technical and scientific processes depend not only upon a measuring system, but lean heavily upon mathematical analysis. Mathematical analysis involves multiplication, division, square roots, and other such calculations. If performed with pencil and paper, these calculations can be boring, time-consuming, and subject to error. The slide rule is a relatively cheap and simple mechanical device which enables you to perfrom calculations faster and with greater accuracy. This minicourse will teach you to use the slide rule for certain simple calculations.

In addition to RATIONALE, this minicourse contains the following sections:

1) TERMINAL BEHAVIORAL OBJECTIVES (Specific things you are expected to learn from the minicourse)

2) ENABLING BEHAVIORAL OBJECTIVES (Learning "steps" to enable you to eventually reach the terminal behavioral objectives)

3) ACTIVITIES (Specific things to do to help you learn)

4) RESOURCE PACKAGES (Instructions for performing the learning Activities, such as procedures, references, laboratory materials, etc.)

5) EVALUATION (Tests to help you learn and to determine whether or not you satisfactorily reach the terminal behavioral objectives)
   a) Self-test(s) with answers, to help you learn more
   b) Final test, to measure your overall achievement.

TERMINAL BEHAVIORAL OBJECTIVES

Upon completion of this minicourse, you will be able to:

1) demonstrate your knowledge of the metric system by converting specific measurements from one metric unit to another (meters to kilometers, for example) and by actually measuring various objects metrically

2) demonstrate your slide rule skills by using your slide rule to solve problems involving the operations of multiplication, division, squaring, cubing, finding square root, and finding cube root.

ENABLING BEHAVIORAL OBJECTIVE #1:	ACTIVITY 1-1	RESOURCE PACKAGE 1-1
Given twenty (20) metric measurements, convert at least sixteen (16) of these to equivalent prescribed metric units within a 15-minute time limit.	Read Resource Package 1-1.	"The French, the Metric System, and the Meter"
	ACTIVITY 1-2	RESOURCE PACKAGE 1-2
	Read Resource Package 1-2.	"Modern Definition of the Meter."
	ACTIVITY 1-3	RESOURCE PACKAGE 1-3
	Read Resource Package 1-3.	"Units for Mass"
	ACTIVITY 1-4	RESOURCE PACKAGE 1-4
	Read Resource Package 1-4.	"The Unit for Time"

ENABLING BEHAVIORAL OBJECTIVE #1	ACTIVITY 1-5	RESOURCE PACKAGE 1-5
(See page 4 for a statement of this objective.)	Read about systems of measure and simple measuring instruments. Your teacher will provide references, if you need them. If you are using Physics, a Basic Science by Frank L. Verwiebe as a text, read pages 3-12.	"Unit Conversions"
	ACTIVITY 1-6	RESOURCE PACKAGE 1-6
	Do the exercises in Resource Package 1-5.	"Answers to Unit Conversions"
	ACTIVITY 1-7	RESOURCE PACKAGE 1-7
	Compare your answers with the answers given in Resource Package 1-6. If you miss more than four (4), ask your teacher for additional aid or instruction.	"Getting It Together Metrically"
	ACTIVITY 1-8	
	Study Resource Package 1-7.	
ENABLING BEHAVIORAL OBJECTIVE #2:	ACTIVITY 2-1	RESOURCE PACKAGE 2-1
Find the linear dimensions, the mass, and/or the volume of four (4) of five (5) designated objects within a 15-minute time limit.	Do the activities in Resource Package 2-1.	"Measurements With a Meter Stick"

ENABLING BEHAVIORAL OBJECTIVE #2	ACTIVITY	RESOURCE PACKAGE
(See page 5 for a statement of this objective.)	Do the activities in Resource Package 2-3.	"Measurements of Volume"
	ACTIVITY 2-3	RESOURCE PACKAGE 2-3
	Do the activities in Resource Package 2-3.	"Measurements of Mass"
	ACTIVITY 2-4	RESOURCE PACKAGE 2-4
	Obtain a stop watch from your teacher. Do Resource Package 2-4. If you need further assistance, ask your teacher.	"Estimating Time Intervals"
	ACTIVITY 2-5	RESOURCE PACKAGE 2-5
	Do Resource Package 2-5.	"Self-test (Metric System)"
	ACTIVITY 2-6	RESOURCE PACKAGE 2-6
	Compare your answers with the answers in Resource Package 2-6. If you miss more than four (4), ask your teacher for assistance.	"Answers to Self-test (Metric System)"
	ACTIVITY 2-7	RESOURCE PACKAGE 2-7
	Do Resource Package 2-7. Your teacher will evaluate your answers.	"Terminal Evaluation (Metric System)"

ENABLING BEHAVIORAL OBJECTIVE #3:

Given twenty (20) problems involving the operations of multiplication and division, use the slide rule to solve at least sixteen (16) problems within a 30-minute time limit.

ACTIVITY 3-1	RESOURCE PACKAGE 3-1
Obtain a slide rule and slide rule manual from your teacher. Locate the C, D, A, and K scales on the slide rule.	"Introduction"
ACTIVITY 3-2	RESOURCE PACKAGE 3-2
Read Resource Package 3-1.	"Parts of the Slide Rule"
ACTIVITY 3-3	RESOURCE PACKAGE 3-3
Study Resource Package 3-2.	"Reading the Slide Rule"
ACTIVITY 3-4	RESOURCE PACKAGE 3-4
Study Resource Package 3-3.	"Locating Numbers on the Slide Rule"
ACTIVITY 3-5	RESOURCE PACKAGE 3-5
Study Resource Package 3-4.	"Slide Rule Multiplication"
ACTIVITY 3-6	RESOURCE PACKAGE 3-6
Study Resource Package 3-5.	"Slide Rule Precision"
ACTIVITY 3-7	RESOURCE PACKAGE 3-7.1
Study Resource Package 3-6.	"Multiplication Self-test"
	RESOURCE PACKAGE 3-7.2
	"Answers to Multiplication Self-test"

ENABLING BEHAVIORAL OBJECTIVE #3:

(See page 7 for a statement of this objective.)

ACTIVITY 3-8	RESOURCE PACKAGE 3-8
Do Resource Package 3-7.1. Check your answers with the answers in Resource Package 3-7.2. If you miss more than three (3), return to Activity 3-7 and review.	"Slide Rule Division"
ACTIVITY 3-9	RESOURCE PACKAGE 3-9
Study Resource Package 3-8.	"Exercises in Division"
ACTIVITY 3-10	RESOURCE PACKAGE 3-10
Do Resource Package 3-9.	"Answers to Division Exercises"
ACTIVITY 3-11	RESOURCE PACKAGE 3-11
Check your answers with the answers in Resource Package 3-10. If you miss more than three (3), go back to Activity 3-9 and review.	"Scientific Notation"
ACTIVITY 3-12	RESOURCE PACKAGE 3-12
Study Resource Package 3-11.	"Exercises in Scientific Notation"
ACTIVITY 3-13	RESOURCE PACKAGE 3-13
Do Resource Package 3-12.	"Answers to Exercises in Scientific Notation"

ENABLING BEHAVIORAL OBJECTIVE #3:

(See page 7 for a statement of this objective.)

ACTIVITY 3-14

Check your answers with the answers in Resource Package 3-13. If you miss more than three (3), go to Activity 3-12 and review.

RESOURCE PACKAGE 3-14

"The Decimal Point (Multiplication)"

ACTIVITY 3-15

Read Resource Package 3-14.

RESOURCE PACKAGE 3-15

"Decimal Point Exercises (Multiplication)"

ACTIVITY 3-16

Do Resource Package 3-15.

RESOURCE PACKAGE 3-16

"Answers to Decimal Point Exercises (Multiplication)"

ACTIVITY 3-17

Check your answers with the answers in Resource Package 3-16. If you miss more than three (3), return to Activity 3-15.

RESOURCE PACKAGE 3-17

"The Decimal Point (Division)"

ACTIVITY 3-18

Study Resource Package 3-17.

RESOURCE PACKAGE 3-18

"Decimal Point Exercises (Division)"

ACTIVITY 3-19

Do Resource Package 3-18.

RESOURCE PACKAGE 3-19

"Answers to Decimal Point Exercises (Division)"

ENABLING BEHAVIORAL OBJECTIVE #3:

(See page 7 for a statement of this objective.)

ACTIVITY 3-20	RESOURCE PACKAGE 3-20
Check your answers with the answers in Resource Package 3-19. If you miss more than three (3), review Activity 3-18.	"Division and Multiplication"
ACTIVITY 3-21	RESOURCE PACKAGE 3-21
Study Resource Package 3-20	"Multiplication and Division Exercises"
ACTIVITY 3-22	RESOURCE PACKAGE 3-22
Do Resource Package 3-21.	"Answers to Multiplication and Division Exercises"
ACTIVITY 3-23	RESOURCE PACKAGE 3-23
Compare your answers with the answers in Resource Package 3-22. If you miss more than three (3), review Activity 3-21.	"Self-test (Multiplication and Division)"
ACTIVITY 3-24	RESOURCE PACKAGE 3-24
Do Resource Package 3-23.	"Answers to Self-test (Multiplication and Division)"
ACTIVITY 3-25	
Compare your answers with the answers in Resource Package 3-24. If you miss more than four (4) problems, ask your teacher for assistance.	

ENABLING BEHAVIORAL OBJECTIVE #4:

Given twenty (20) problems involving the operations of squaring, cubing, and extracting square root and cube root, use the slide rule to solve at least sixteen (16) of these problems within a 30-minute time limit.

ACTIVITY 4-1	
Read Resource Package 4-1.	RESOURCE PACKAGE 4-1 "The Square of a Number"
ACTIVITY 4-2	
Do Resource Package 4-2.	RESOURCE PACKAGE 4-2 "Exercises (Squares of Numbers)"
ACTIVITY 4-3	
Compare your answers with the answers in Resource Package 4-3. If you miss more than three (3), review Activity 4-2.	RESOURCE PACKAGE 4-3 "Answers to Exercises (Squares of Numbers)"
ACTIVITY 4-4	
Study Resource Package 4-4.	RESOURCE PACKAGE 4-4 "Square Root of a Number"
ACTIVITY 4-5	
Do Resource Package 4-5.	RESOURCE PACKAGE 4-5 "Exercises (Finding Square Roots)"
ACTIVITY 4-6	
Check your answers with the answers in Resource Package 4-6. If you miss more than three (3), return to Activity 4-4.	RESOURCE PACKAGE 4-6 "Answers to Exercises (Finding Square Roots)"
ACTIVITY 4-7	
Study Resource Package 4-7.	RESOURCE PACKAGE 4-7 "The Cube of a Number"
ACTIVITY 4-8	
Do Resource Package 4-8.	RESOURCE PACKAGE 4-8 "Exercises in Cubing"

ENABLING BEHAVIORAL OBJECTIVE #4:

(See page 11 for a statement of this objective.)

ACTIVITY 4-9	RESOURCE PACKAGE 4-9
Compare your answers with the answers in Resource Package 4-9. If you miss more than three (3), go to Activity 4-7.	"Answers to Exercises in Cubing"
ACTIVITY 4-10	RESOURCE PACKAGE 4-10
Study Resource Package 4-10.	"Finding the Cube Root of a Number"
ACTIVITY 4-11	RESOURCE PACKAGE 4-11
Do Resource Package 4-11.	"Exercises in Finding Cube Roots"
ACTIVITY 4-12	RESOURCE PACKAGE 4-12
Compare your answers with the answers in Resource Package 4-12. If you miss more than three (3), go to Activity 4-10.	"Answers for Exercises with Cube Roots"
ACTIVITY 4-13	RESOURCE PACKAGE 4-13
Study Resource Package 4-13.	"Self-test (Slide Rule)"
ACTIVITY 4-14	RESOURCE PACKAGE 4-14
Compare your answers with the answers in Resource Package 4-14. If you miss more than four (4), ask your teacher for assistance.	"Answers to Self-test (Slide Rule)"
ACTIVITY 4-15	RESOURCE PACKAGE 4-15
Do Resource Package 4-15. Turn your answers in to your teacher for evaluation.	"Terminal Evaluation (Slide Rule)"

RESOURCE PACKAGE 1-1

THE FRENCH, THE METRIC SYSTEM, AND THE METER

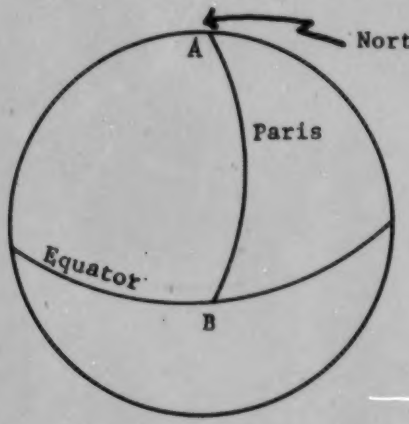
Measurement may be defined as the comparison of an unknown quantity with a standard quantity. The standard quantity is referred to as a unit. In any system of measure, length and time and something called mass are the basic mechanical units. Our English system of measure evolved in a diverse and haphazard manner, somewhat in the same fashion that a town or city grows when there is no city planning. For example, the inch was once the length from a man's thumb knuckle to his thumb tip; the foot was once defined as 36 barleycorns (grains of barley) laid end to end; a yard was taken as the distance from the tip of the nose of England's King Edgar to the end of his middle finger; an acre was the amount of land plowed by an ox in one day, etc.

About 250 years ago (the time of the French Revolution, circa 1790), the French Academy of Science developed a completely new system of measure using a decimal number base and precise standards. This French metric system (The International Scientific System) has been adopted by scientists in all countries and is used by the everyday citizens of nearly all the non-English speaking countries of the world.

The meter is the standard of length in the metric system. The meter was defined to be 1/10,000,000 of the distance from the equator to the north pole, along a meridian passing through Paris, so that

the distance could be redetermined if the original standard were lost (See Fig. 1). This length was carefully recorded on a bar of platinum-iridium alloy and was housed at the International Bureau of Weights and Measures near Paris, France. A standard meter was then defined to be the distance between two lines near each end of this bar when the temperature of the bar was $0^{o}C$. (This standard bar later was found to be in error by approximately 0.023%.) Since it is impractical to transport the primary standard bar from one place of measurement to another, copies of the bar (called secondary standards) are made. These copies are distributed to the standardizing agencies of various nations, such as our National Bureau of Standards in Washington, D.C. Common wooden meter sticks are calibrated from secondary standards and prove precise enough for ordinary measurements.

Subsequent Resource Packages will teach you about the other two fundamental units of measure, time and mass.



THE ORIGINAL METER
Fig.1

1 meter = 1/10,000,000 the distance from A to B along the surface of the earth, as defined in the year, 1791; the modern definition is presented in Resource Package 1-2.

RESOURCE PACKAGE 1-2

MODERN DEFINITION OF THE METER

"There once was a student named Peter
Who asked, "Why use meter and liter?"
But when he found out,
He let out this shout:
" 'Cause meter and liter are neater!"

In 1960, a new definition of the standard meter was adopted. The meter is now defined to be exactly 1,650,763.71 wavelengths of the orange light emitted by atoms of krypton-86. It is a simple matter for physicists anywhere in the world to reproduce this light (standard meter). Therefore, this new definition did not alter the length of the previous meter nor require the manufacture of new meter sticks. It merely provides a standard which is available universally, is unchangeable, and is always reproducible precisely. The yard is now defined in all English-speaking nations as 3.600/3.937 meters. Hence, the same physical standard serves for the yard and the meter.

The meter (m) is the standard unit of length in the metric system. However, if we measure both very small and very large distances with a meter stick, we soon find that this is inconvenient. For greater convenience, submultiples and multiples of the meter have been defined (See Table 1). Notice that one-tenth of a meter is a decimeter (dm); one-hundredth is a centimeter (cm); and one-thousandth is a millimeter (mm). Ten meters is a dekameter (dk); one hundred meters is a hectometer (hm); and

one thousand meters is a kilometer (km). For very small measurements, a micron (μ), one-millionth of a meter and an angstrom ($\mathring{A}$), one ten-billionth of a meter, are used. Example measurements in this system follow: the wavelength of red light is approximately 6,700 $\mathring{A}$; an approximate diameter of the piston of some automobile engine might be ten (10) centimeters; and the distance between Dallas and New York is roughly 2,250 kilometers.

METRIC UNITS OF LENGTH

		Meters	
1 kilometer	(km)	1,000	10^3 m
1 meter *	(m)	1	10^0 m
1 decimeter	(dm)	$\frac{1}{10}$	10^{-1} m
1 centimeter	(cm)	$\frac{1}{100}$	10^{-2} m
1 millimeter	(mm)	$\frac{1}{1,000}$	10^{-3} m
1 micron	(μ)	$\frac{1}{1,000,000}$	10^{-6} m
1 angstrom	($\mathring{A}$)	$\frac{1}{10,000,000,000}$	10^{-10} m

* (The Standard Unit)

TABLE 1

By using multiples of ten (10), we are able to convert from one unit to another very easily. Two meters equal 2 x 100 cm, or 200 cm. Likewise, 2.5 km = 2.5 km (1,000 m/km) = 2,500 meters. If you convert from a smaller unit to a larger unit, the decimal point will move to the left; conversely, to convert from a larger unit to a smaller unit, the decimal point will move to the right.

Sample #1: Change 1.6 m into cm

Solution: 1.6 m = 1.6 m x 100 cm/m = 160 cm

Sample #2: Change 2.3 mm to cm

Solution: $2.3 \text{ mm} \left(\frac{1}{10 \text{ mm/cm}}\right) = .23 \text{ cm}$

In a letter to the editor of a popular magazine, a confused reader wrote:

> Our system of measurement may be based on barleycorns, but what's the metric system based on? The meter is supposed to be an equal division of the distance between the poles. Science has proved that the meter is not an equal division of the distance between the poles. And even if this measurement were calibrated to the nth degree, isn't the earth constantly changing? What in the universe doesn't change? You have to start somewhere, so why not start with barleycorns?

Critically analyze the reader's letter. Imagine you are the editor. Write a response to this letter.

Submit this response to your teacher for evaluation.

RESOURCE PACKAGE 1-3

UNITS FOR MASS

You are cautioned to be careful with the words "mass" and weight." Think about these two common uses of the word "weight": (1) as a property (characteristic of a thing), such as "Its weight makes it difficult to lift." and (2) as a thing, such as "Hand me a 2-lb weight." Because this word "weight" has been a part of your vocabulary for so many years, using the word for two entirely different concepts does not cause you difficulty.

But be careful with the following two common usages of the word "mass," because this word has not been a part of your vocabulary: (1) as a property of a thing, such as "The 'mass' property (quality) of an object is the measure of its inertia (resistance to force; to being shoved around; to having its existing motion changed); and (2) as a force equivalent, such as "A mass of one kilogram is equivalent to a weight of 2.2 pounds."

Technically, we prefer to define mass as a measure of an object's resistance to force (inertia); but we recognize that historically the word "mass" has come to mean a measure of the amount or quantity of some substance.

The metric standard for an object's mass property is the kilogram, which is defined as the mass property of a standard block of platinum-iridium alloy kept at the International Bureau of Weights and

Measures in Paris, (where the standard meter is also stored.) The mass of the standard kilogram (kg) is the approximate equivalent of 2.2 pounds of any substance, and one liter of water has an approximate mass of 1 kg.

Common sub-multiples of the kilogram are the gram and milligram as shown below.

Some Metric Units of Mass

1 kilogram = 1,000 grams
1 gram = 1,000 milligrams
1 kilogram = 1,000,000 milligrams

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RESOURCE PACKAGE 1-4

THE UNIT FOR TIME

The basic unit of time in all systems of measure is the second. The definition of the second has changed over the years. At one time the second was defined as:

$$1 \text{ second} = \frac{1}{86{,}400} \text{ part of one mean solar day}$$

The mean solar day was the average length of a day based upon the number of days (earth rotations) in a year. But because of irregularities in the rotation of the earth, this definition produced a slight error. To offset this rotational error, the standard second was defined in terms of the frequency of vibration of the cesium-133 atom. The current value for the standard second is 9,192,631,770 vibrations of the cesium-133 atom.

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RESOURCE PACKAGE 1-5

UNIT CONVERSIONS

Copy the following problems on notebook paper and express the measurements in terms of the units indicated on the right.

1) 50 mm = _____ cm

2) 20 m = _____ cm

3) 30 cm = _____ m

4) 165 mm = _____ m

5) .1 m = _____ cm

6) 86.1 mm = _____ cm

7) 2.6 m = _____ mm

8) .125 cm = _____ mm

9) 2 μ = _____ cm

10) 5A^{o} = _____ cm

11) 4.13 cm = _____ mm

12) 16 kg = _____ gm

13) 281.3 gm = _____ kg

14) 2 m^3 = _____ cc

15) 1875 cc = _____ m^3

16) 4.01 = _____ ml

17) 76.5 ml = _____ l

18) 22 ml = _____ cc

19) 3.1 L = _____ cc

20) 50 cc = _____ l

If you are in doubt about the comparative simplicity of the metric system, ask yourself how many sixteenths of an inch there are in a mile! The number of millimeters in a kilometer is a million times easier to calculate.

Now, calculate the number of mm in a km and see if you can tell why it might be a "million times easier to calculate."

Discuss your answer with your teacher.

RESOURCE PACKAGE 1-6

ANSWERS TO UNIT CONVERSIONS

Answers for Resource Package 1-5

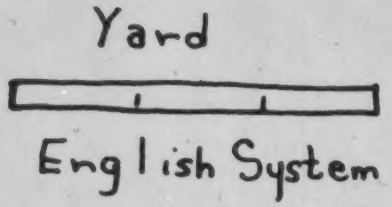
1) 5
2) 2,000
3) .3
4) .165
5) 10
6) 8.61
7) 2,600
8) 1.25
9) .0002
10) 50,000,000
11) 41.3
12) 16,000
13) .2813
14) 2,000,000
15) .0001875
16) 4,000
17) .0756
18) 22
19) 3,100
20) .05

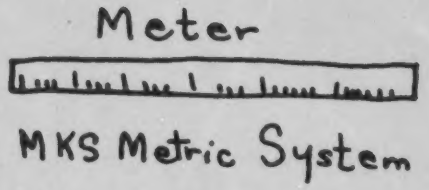
RESOURCE PACKAGE 1-7

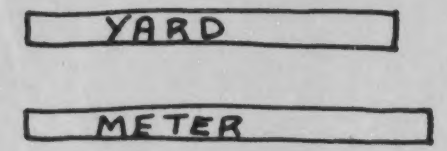
GETTING IT TOGETHER METRICALLY

You have been introduced to three basic units of measure in the metric system, each of which can be reproduced (standardized) anywhere in the world using scientific means. These three units form the meter-kilogram-second (MKS) system of measure, which is in current use throughout the scientific world and in most countries of the world. As we study other areas of physics, we will use these three basic units to develop other units for measuring physical quantities. These new units are called derived units and they enable us to measure such entities as force, velocity, acceleration, energy, area, volume, work, power, and whatever else we choose to measure.

This resource package is designed to introduce you to some relationships between standard units of measure. On the following pages, both the English system and the metric system are used to show these relationships.







The yard is a derived unit of length in the English system.

Its equivalent is about one meter in the MKS Metric System (The meter is slightly longer; 1 m≈3 English feet.)

The meter stick is slightly longer than the yard stick.

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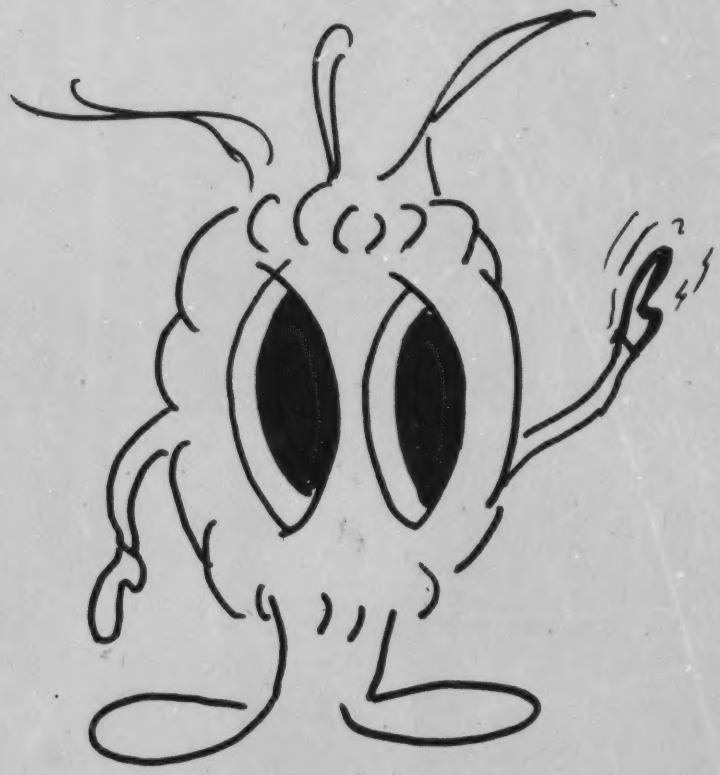
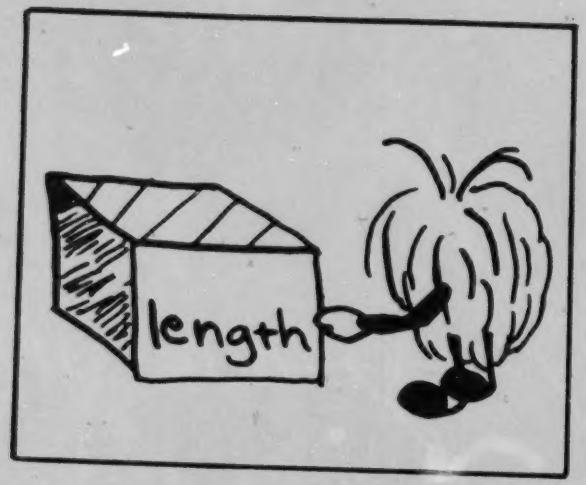
Now, meet Eyestein. He will take you on a kind of guided tour of the three basic building blocks of all systems of measure; namely, the standard units of length, of time, and of mass. He'll also guide you through some relationships between the English system and the metric system. Here is Eyestein:



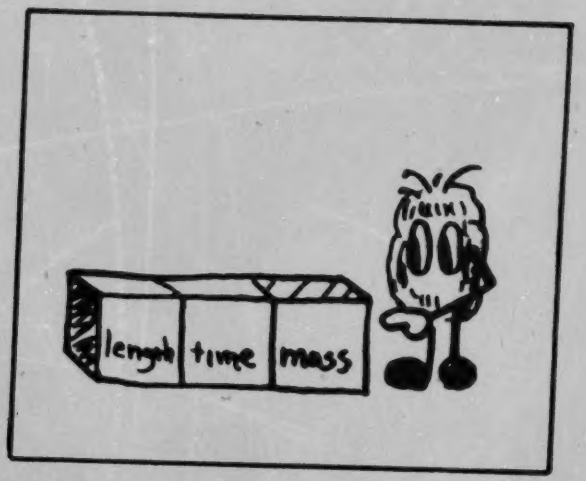
Hi! Eyestein's my name... and

Physics is my game!

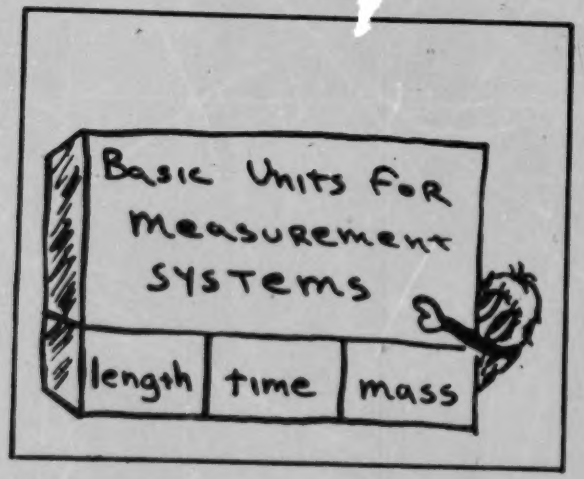


Having learned that standard units of length

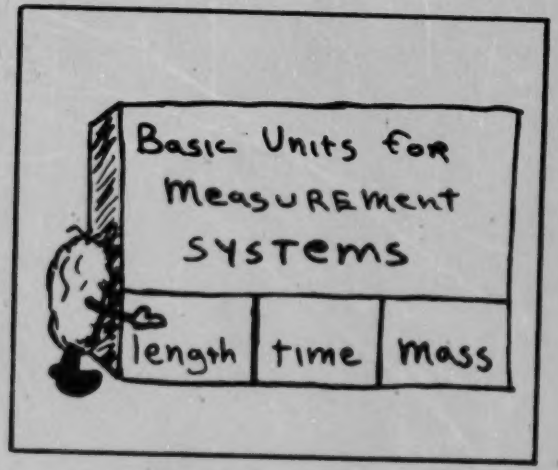
time, and



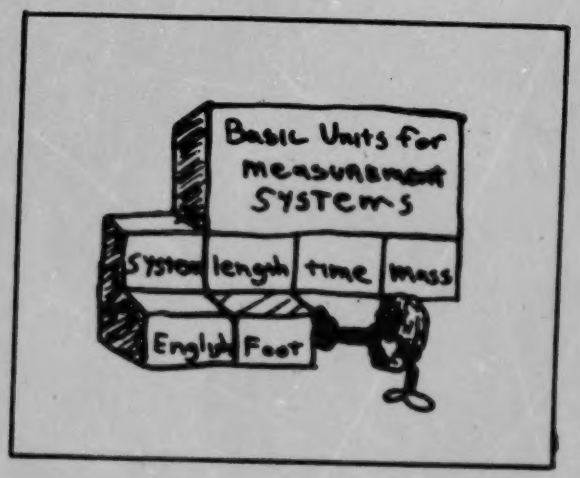
something called mass



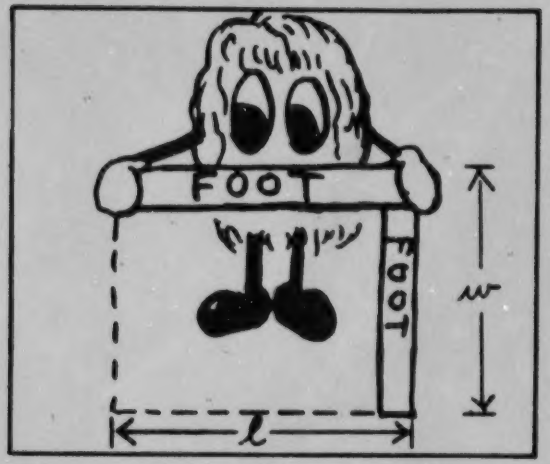
are the building blocks for complete systems of measurement, you will be shown how familiar physical measurements are derived from these basic units.



For example, let us see how one "builds" area and volume from the basic unit of length.



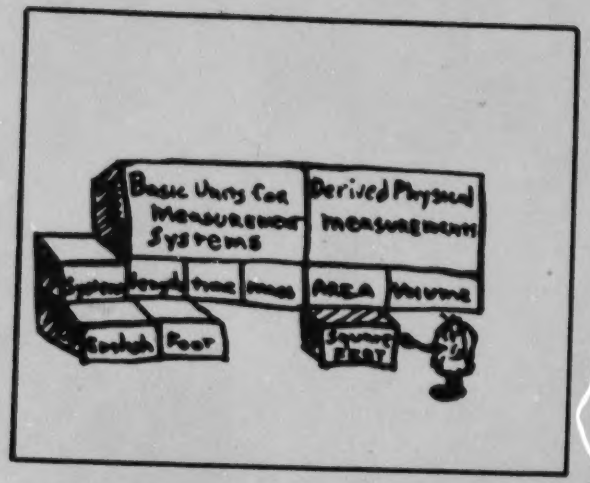
We know that the foot is the basic unit of length in our everyday system of measurement.

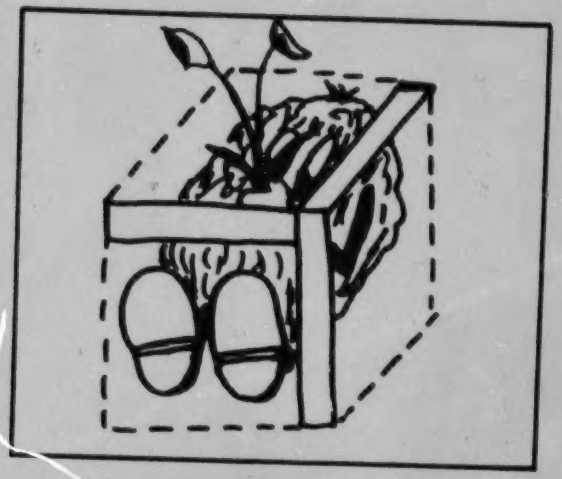


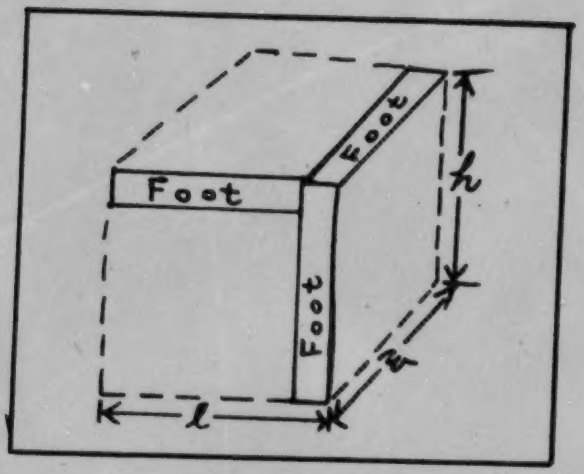
Remember that a ruler represents the basic unit of length, the foot.

One sees that the length of this square multiplied by its width requires multiplying the length unit feet, times the width unit feet;

and the product results in an area measurement expressed in square feet (ft x ft = ft^2).



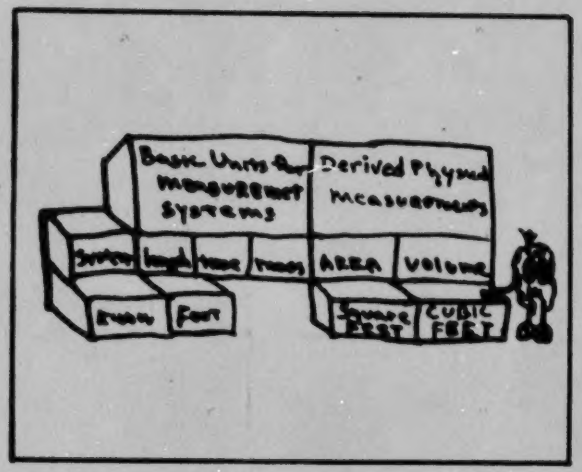




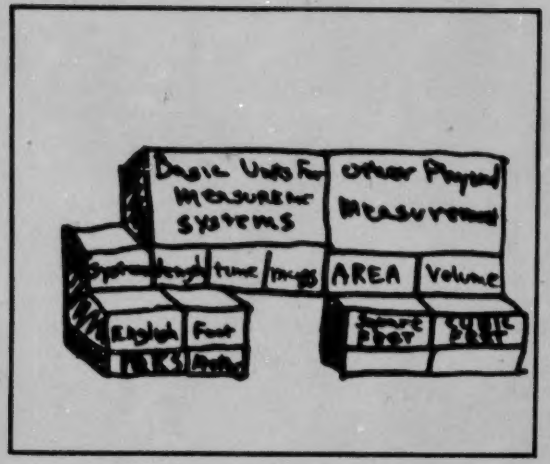
Our cartoon friend has entered "square feet" on the chart under the box titled Derived Physical Measurements, Area.

Now, notice that a length unit multiplied by a width unit multiplied by a height unit (units of feet times feet times feet)

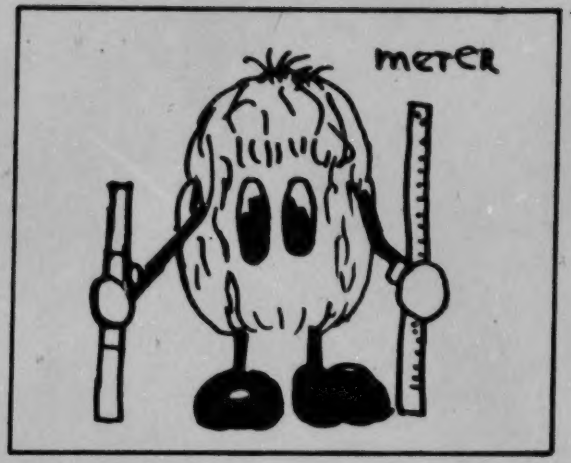
yields the derived volume measure called cubic feet ($ft \times ft \times ft = ft^3$).



Our friend has entered "cubic feet" on our chart under the English system box for Volume.



Let's look at the same problem worked in the MKS Metric System.



The basic unit of length is the meter, a unit slightly longer than 3 feet (one yard, plus).

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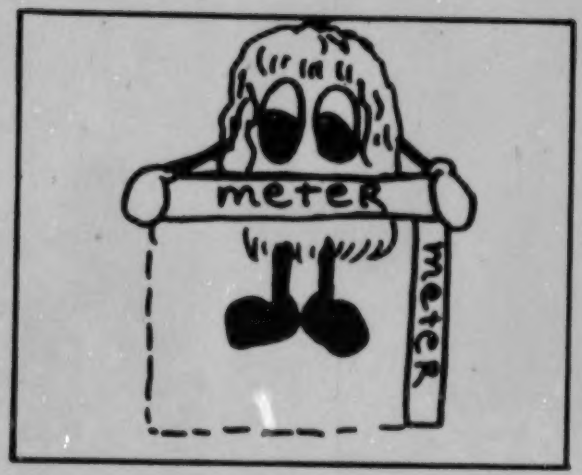
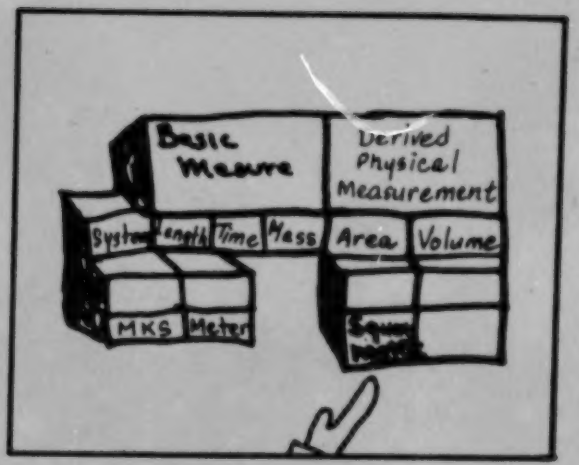


As was done in the English system, a meter unit multiplied by a meter unit (length times width) yields an area measurement ($m \times m = m^2$ = square meters).

Here we see a square meter--a surface or square whose sides are one meter in length. Remember that one meter is approximately 3 ft; a square meter is easily seen to be 3 ft times 3 ft or 9 ft squared.



The square meter can now be placed in the Area measurement square.

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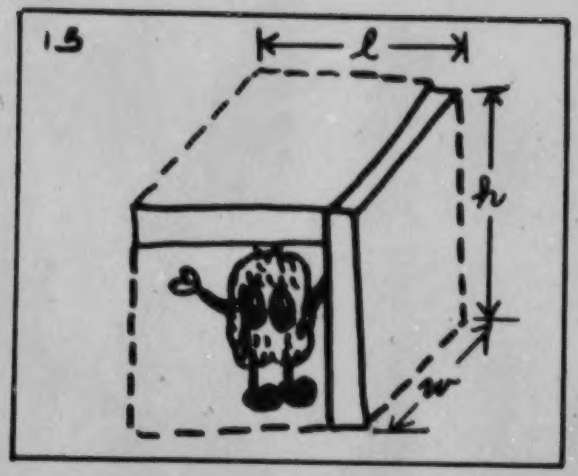
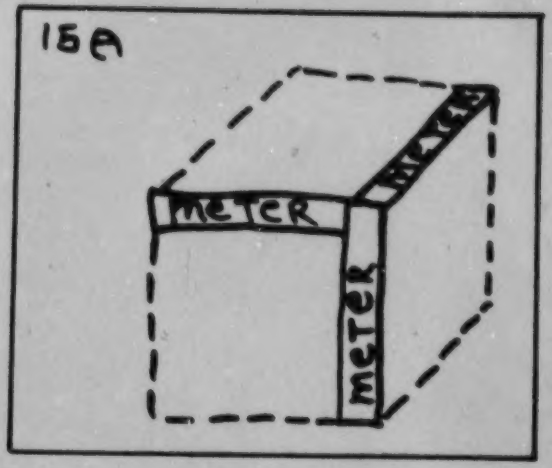
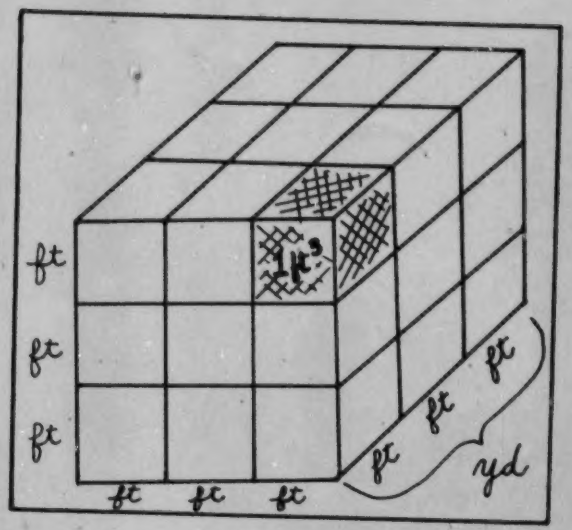




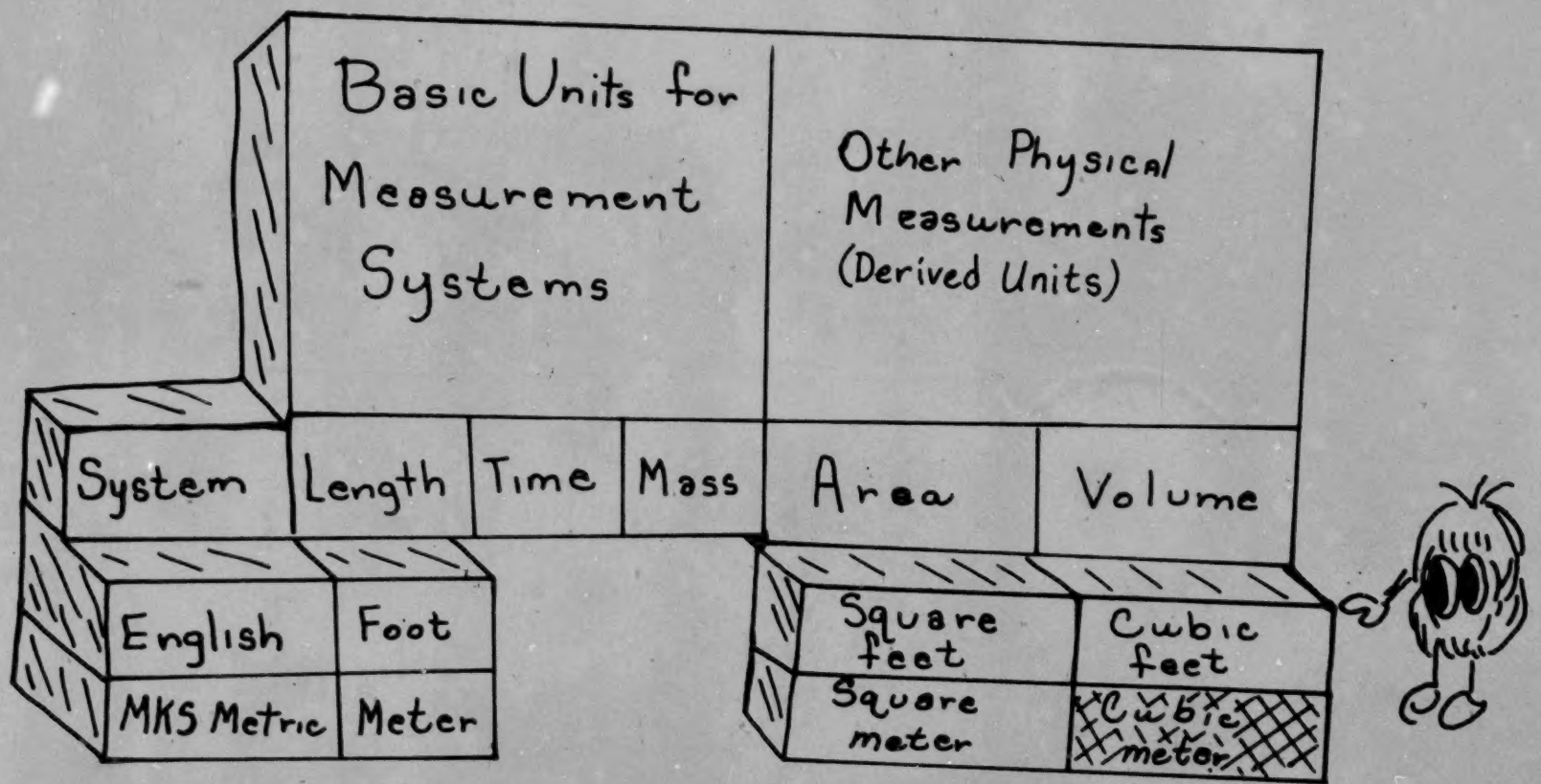
Next, cubical volume can be calculated in the MKS Metric System by multiplying a length times a width times a height, or

meters times meters times meters yields a volume in units of cubic meters ($m \cdot m \cdot m = m^3$).



To compare our metric volume to the English volume, it is easy to see that if one meter is approximately one yard (3 feet), then a cubic meter is approximately the product of 3 ft times 3 ft times 3 ft, or about 27 cubic feet (3 ft x 3 ft x 3 ft = $(3)^3(ft)^3 = 27\ ft^3$)

Which Eyestein has conveniently entered on our chart under the Metric System box for <u>volume</u>.



Eye-stein proves that a "30-cm dog" ≈ "foot-long dog".

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Now, let's examine some English-metric comparisons:

1) A liter is a little more than a quart (about 1.06 quarts).

To Do: a) Fill a quart container with water. Pour this quart of water into a liter flask. Are you convinced that a liter is slightly more than a quart?

b) Compare 5 cc of water to one teaspoonful of water (This is $\approx$ 5 grams of water). Use a teaspoon and a graduated cylinder to make this comparison.

2) A meter is about three and one-half ($3\frac{1}{2}$) inches longer than a yard. (For rough approximations, we say a meter is about one yard.)

To Do: a) If you are six (6) feet tall, you are about _____ meters tall?

b) If you were two (2) yards tall, and if your opponent were two (2) meters tall, then he would have approximately _____ inches advantage over you if you two were jumping center on the basketball court. Do you consider this difference to be significant?

3) In a metric classroom you can speak freely of a dam street! You see, if you laid ten (10) meter-sticks end to end, they would span one decimeter (1 dam), or about the width of some city streets ($\approx$ 33 ft).

To Do: Compare a 400-m race to a 440-yd race: The 440-yd distance is _____ feet (3 ft/yd)(440 yd). A 400-m race is about _____ feet (3 ft/m)(400 m). More precisely, the conversion would be (400 m)(3.3 ft/m, or _____ feet. This is a little more than $\frac{1}{2}$ a mile ($\approx$ 6/10 mile).

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4) A kilogram mass has a weight equivalence of about 2¼ lbs. This means that a ¼-pound stick of butter, plus a 1-pound package of butter would weigh nearly the same as the platinum-iridium 1-kg standard mass cylinder in Paris, France.

To Do: Examine a nickel. Its mass is ≈5 grams.

5) A standard-sized paper clip has a width of about 1 centimeter, and a wire diameter of about a millimeter. Is a mm smaller than, equal to, or larger than the diameter of human hair?

6) Change these quotations from English to metric:

a) "Give him an inch (_____ cm), and he'll take a mile (_____ km)."

b) "He wore a ten-gallon (_____ liter) hat and said he hailed from Dallas."

c) Her grandmother advised, "An ounce (_____ grams) of prevention is (are) worth a pound (_____ kilograms) of cure."

d) The President declared, "I wouldn't touch that tape with a ten-foot (_____ meter) pole."

e) Narrowly escaping the deadly horns, the matador calmly commented, "A miss is as good as a mile (_____kilometers)."

f) "Would you describe her as the kind who would "swallow a camel, but choke on a gnat," or would "penny-wise but pound (_____ kilogram) foolish" be more descriptive?

g) A coal miner's song has the lyric, "I load sixteen tons (_____ tonnes) and what do I get?" "One day older and deeper in debt." "I owe my soul to the company store!"

h) Remember the old-time lyric, "Five-feet two (_____ m) and eyes of blue"?

i) "The 350-cubic inch (350 cc) racing engine has a displacement of _____ liters," said the Unser brothers.

RESOURCE PACKAGE 2-1

MEASUREMENTS WITH A METER STICK

a) Examine a meter stick and identify the millimeter, centimeter, and decimeter marks. If you need help, consult your teacher.

Record your answers to the following on notebook paper:

b) Use the meter stick to determine the length and width of your textbook in centimeters.

c) Determine the length and width of your classroom in meters.

d) Determine your height in centimeters and convert this to millimeters.

e) Compare your measurements with similar measurements made by two or three members of your class. Ask your teacher for help if additional instruction is needed.

RESOURCE PACKAGE 2-2

MEASUREMENTS OF VOLUME

Record your answers to parts a, b, d, and e, below, on notebook paper:

a) Using a meter stick determine length, width, and thickness of your textbook in centimeters. Using the formula, V = L x W x H, find the textbook volume in cubic centimeters (cc).

b) Find the volume of a block of wood supplied by your teacher. Express your answer in cubic centimeters and in cubic meters.

c) Examine a graduate (graduated flask, cup, or cylinder) supplied by your teacher. Note the millimeter markings. If necessary, ask your teacher to explain how to read the graduate.

d) Using a tin can supplied by your teacher, fill it with water. Next, pour this water into the graduate to determine the volume of the can.

e) Using the can in part "d" above, place a small rock about one inch wide into the can. Pour water into the graduate to determine the volume of the water. Subtract this measure from the measure found in part "d," above, to obtain the volume of the rock. Now determine the volume of several common items (coin, keys, etc.), using this same procedure.

f) Discuss your results with another member of your class.

g) Ask your teacher to check your results.

RESOURCE PACKAGE 2-3

MEASUREMENTS OF MASS

a) Obtain a triple beam balance and a set of standard metric masses from your teacher. Note that the word "mass" is used here to mean a thing; i.e., an object (a meaning which has evolved historically). A second and more scientific meaning of "mass" is that of a property or characteristic of a thing, i.e., a measure of the resistance something offers to force effects (a measure of something's inertia).

b) Using the standard masses, determine how to operate the balance so you can measure the mass property of an object whose mass is not known. If you have problems or questions, ask your teacher for help.

c) Obtain three objects of unknown mass from your teacher. Determine the mass of each in grams and record your answers on notebook paper. Convert these measurements to kilograms and to milligrams.

d) Ask your teacher to check your work and to give you assistance if you have problems.

RESOURCE PACKAGE 2-4

ESTIMATING TIME INTERVALS

With the second hand of a stop watch set at 0, start the watch and stop it after 20 seconds. Repeat this for 15-, 20-, and 30-second time intervals. Now start the watch and without looking at the second hand estimate 15 seconds, stopping the watch when you think that 15 seconds have elapsed. How close was your guess? Repeat the above procedure and estimate 30-, 45-, and 60-second intervals. Can you think of a sport or vocation where estimation of time interval is essential?

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RESOURCE PACKAGE 2-5

SELF-TEST (METRIC SYSTEM)

A. 1) Given a block of wood, find its length, width, and height in mm.
2) Find the volume of the block in part (1). Express your answer in cc and m^3.
3) Use the triple beam balance to determine the mass of the block in part (1). Express your answer in grams.
4) Find the mass of an irregular solid object supplied by your teacher. Express your answer in grams and kilograms.
5) Find the volume of a small container supplied by your teacher. Use the graduate and tap water.
6) Using the results and materials in part (5), find the volume of the object used in part (4). Express your answers in cc.
7) Using a different irregular object, find its volume according to part (6).

B. Express the following measurements in terms of the units indicated on the right.

1) 25 cc = _____ ml
2) 7,000 cc = _____ cubic meters
3) 40 gm = _____ kg
4) .2 m = _____ cm
5) 5 cm = _____ mm
6) .01 cubic meters = _____ cc
7) 20 Å = _____ cm
8) 2 mm = _____ μ
9) 14.1 cm = _____ mm
10) 251.6 gm = _____ kg

RESOURCE PACKAGE 2-6

ANSWERS TO SELF TEST (METRIC SYSTEM)

A. Ask your teacher to check your work.

B.

1)	25	6)	10,000
2)	.007	7)	.0000002
3)	.04	8)	2,000
4)	20	9)	141
5)	50	10)	.2516

RESOURCE PACKAGE 3-1

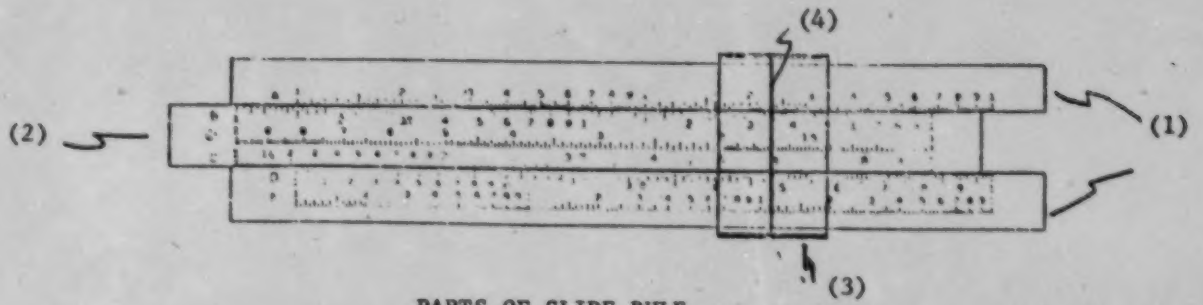
INTRODUCTION

This portion of the minicourse will teach you how to perform some basic slide rule operations. The slide rule manual explains the use of scales which you will not use at this time. Read about the C and D scales. Practice reading and using these scales, as prescribed in the manual. Ask your teacher for assistance whenever needed. As you progress through this minicourse, it is recommended that you refer to those sections of the slide rule manual which explain further the slide rule operations you are studying. The manual explains and illustrates in detail all of the slide rule topics covered in this minicourse.

RESOURCE PACKAGE 3-2

PARTS OF THE SLIDE RULE

The slide rule consists of three parts: 1) the body (upper and lower fixed bars), 2) the slide, and 3) the indicator. The fine vertical line on the indicator, (4), is called the hairline (See Fig. 1 below).



PARTS OF SLIDE RULE

Fig. 1

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RESOURCE PACKAGE 3-3

READING THE SLIDE RULE

Some of the scales on the slide rule are identical. C and D are identical and A and B are identical. Look at scale C and note the numbers printed on the slide. This scale has ten major divisions starting with the figure 1 (called the left index) on the left, and ending with the figure 1 (called the right index) on the right. The 1 on the right stands for 10! Observe that the decimal point is not present on the slide rule scales. Later on, you will be taught how to locate the decimal point. See Fig. 2 below and note that the numbers which represent the ten basic divisions are not the same distance apart. This is because the scales are based on logarithmic numbers; however, you do not need to know the theory of logarithms to be able to use the slide.

SLIDE RULE NUMBERS (C SCALE)

Fig. 2

The major divisions are divided into 10 secondary divisions. The secondary divisions between the left index and the 5 are divided into smaller divisions. When we set a number on the slide rule we usually expect to work with no more than three digits of that number. So if we want to work with the number 4,622 we round off to 4,620 (three significant digits) and set 462 on the

slide rule. You can see that the slide rule will give us approximate answers. Approximate answers have universal application in science and technology.

Using the C scale, set the hairline directly over the long mark between the 2 and 3. This setting could stand for 25, 250, 2,500, 2.5, .25, .0025, or .00025. Remember, the decimal point is not present on the slide rule. Next, set the hairline on the fourth line between 5 and 6. This setting represents 54. It could also represent 5.4, 540, 54,000, or .00054. Now set the hairline halfway between the 3rd and 4th subdivision between 7 and 8. This setting represents 735. You have probably discovered by now the inaccuracy (difficulty) of setting the third digit, especially on the right hand side of the scale. With practice you will overcome some of this inaccuracy. See Fig. 3, below, and try setting the numbers in the figure on your slide rule.

NUMBERS ON C SCALE

Fig. 3

Ask your teacher for assistance if you need help.

RESOURCE PACKAGE 3-4

LOCATING NUMBERS ON THE SLIDE RULE

Set the following numbers on the C scale under the hairline:

1) 4.21

2) 6.82

3) .0926

4) 884.

5) 98.2

6) .00545

7) 1.09

8) 2.57

If you have any difficulty, ask your teacher for assistance.

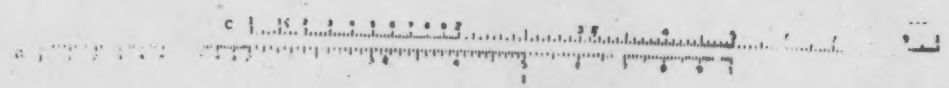
RESOURCE PACKAGE 3-5

SLIDE RULE MULTIPLICATION

Multiplication on the slide rule involves the C and D scales. To multiply, set the first multiplier on the D scale under the index of the C scale. Then set the second multiplier on the C scale under the hairline. The answer will be on the D scale under the hairline. If the number on the C scale is beyond the index of the D scale, rendering its setting impossible, push the slide in the opposite direction and set the other index of the C scale over the first multiplier on the D scale. Again, the answer will be under the hairline on the D scale.

Example #1: Multiply 2 x 3 on the C and D scales.

Solution: Set 2 on the D scale under the left index of the C scale. Then set 3 on the C scale under the hairline. Read 6 on the D scale under the hairline (See Fig. 4 below).



MULTIPLICATION
Fig. 4

Example #2: Multiply 21 x 58

Solution: Set 21 on D under the right index of C. Then set 58 on C under the hairline. Read the answer 121 or 122 on D under the hairline. The exact answer is 1,218, but we are not expected to read more than 3 places on the slide rule. The answer of 1,218 would round off to 1,220, which has the digits, 1, 2, and 2, as its first three digits. (This slide rule number 122 doesn't tell us the decimal point location; but we are not concerned with the decimal point now. It will be discussed in depth later.)

Example #3: Multiply .0162 x 17.3

Solution: Ignore the decimal points and work with the digits, 1, 6, 2, and 1, 7, 3. Set 162 on D under the left index of C and set 173 on C under the hairline. Read 280 under the hairline on D. The answer is not 280., as is obvious from the factors (multipliers). You will learn to set decimal points later.

RESOURCE PACKAGE 3-6

SLIDE RULE PRECISION

Because useful technology does not require absolutely perfect answers, we neither need nor expect such exact answers from the slide rule. If the answer to a calculation is 455, any result obtained on the slide rule between and including 453 and 457 would be acceptable. (Slide rule accuracy is said to be ± 2 for the third digit; in our example, 455 is 453 + 2 and is 457-2). Only the first two digits must be exact. Slide rules can usually be read accurately to three digits. If you were to read an answer as exactly 26, you would generally record the third digit as zero to produce the answer 260 (which has the three digits of expected accuracy); then you would place the appropriate decimal point: .026; .260; 2.60; 26.0; etc.

RESOURCE PACKAGE 3-7.1

MULTIPLICATION SELF-TEST

Multiply the following numbers on the slide rule and record 3-digit answers on notebook paper. Ignore the decimal point.

1) 28 x 12
2) 86 x 142
3) 4.10 x 34.2
4) 87.2 x .931
5) .421 x .0112
6) 94.3 x 34.6
7) .0091 x .0141
8) 431. x .421
9) 86.2 x .0199
10) .622 x .00932

RESOURCE PACKAGE 3-7.2

ANSWERS TO MULTIPLICATION SELF-TEST

1) 336

2) 122

3) 140

4) 812

5) 472

6) 326

7) 128

8) 181

9) 172

10) 580

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RESOURCE PACKAGE 3-8

SLIDE RULE DIVISION

Division on the slide rule involves the C and D scales and is the reverse operation of multiplication.

Example #1: Divide 26 by 4
Solution: Set 26 on D under the hairline; then move the slide so that 4 on C is set under the hairline. Make sure that the indicator does not move. Read the answer 650 on D under the index of C. Remember, always calculate to 3 digits on the slide rule. Ignore decimal points for now.

Example #2: Divide .0976 by 86.4
Solution: Ignore the decimal points and work with the digits 9, 7, 6, and 8, 6, 4. Set 976 on D under the hairline. Then move the slide so that 864 is set under the hairline. Read 113 on D under the index of C.

RESOURCE PACKAGE 3-9

EXERCISES IN DIVISION

Divide the following problems using the slide rule and record three-digit answers on notebook paper. Ignore decimal points.

1) $\frac{28}{16}$

2) $\frac{46.1}{14}$

3) $\frac{8.61}{.931}$

4) $\frac{46.4}{.0321}$

5) $\frac{58.6}{87.2}$

6) $\frac{14.1}{2.6}$

7) $\frac{877.}{321.}$

8) $\frac{928}{.0112}$

9) $\frac{.0362}{.00134}$

10) $\frac{436.2}{.0319}$

RESOURCE PACKAGE 3-10

ANSWERS TO DIVISION EXERCISES

1) 175

2) 329

3) 925

4) 145

5) 672

6) 542

7) 273

8) 829

9) 270

10) 137

RESOURCE PACKAGE 3-11

SCIENTIFIC NOTATION

There are many methods used to place the decimal point once the three-digit answer is obtained. One method is known as inspection. If we divide 33 by 2, we read 165 on the slide rule. The decimal point would obviously go between the 6 and 5, making the final answer read 16.5. Sometimes the position of the decimal point is not so easy to establish. The concept of scientific notation will help us to establish the decimal point with accuracy and with ease. Consider the number 876, which may be written as 8.76×100 or 8.76×10^2. The number 485. and .00338 may be written respectively as:

$$485 = 4.85 \times 100 = 4.85 \times 10^2$$

and

$$.00338 = \frac{3.38}{1000} = \frac{3.38}{10^3} = 3.38 \times 10^{-3}$$

The expression 4.85×10^2 is the scientific notation form for 485, while 3.38×10^{-3} is the scientific notation form for .00338. Each of these numbers is written in terms of powers of ten. Note that there is only one digit to the left of the decimal point. The number of places the decimal point is moved determines the number used as the exponent on 10. If the decimal point is moved to the left, the number (exponent) on 10 is positive, while the number (exponent) on 10 is negative if the decimal point is moved to the right. The exponent on 10 is also known as a power; and when a number is written in scientific notation, it is said to be written in powers of 10.

Example #1: Write 376 in scientific notation.

Solution: $376. \times 100 = 3.76 \times 10^2$ (Note that a decimal point was moved left. The exponent 2 on 10 is positive.)

Example #2: Write .00186 in scientific notation.

Solution: $.00186 = 1.86 \times 10^{-3}$ (Note that this exponent was moved right. How does the sign of the exponent in this example differ from example #1?)

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RESOURCE PACKAGE 3-12

EXERCISES IN SCIENTIFIC NOTATION

Copy the following problems on notebook paper. Next, express them in scientific notation.

1) 65.1

2) 483.

3) .0111

4) .00761

5) 860.

6) .911

7) .0909

8) 4.80

9) .562

10) .0643

RESOURCE PACKAGE 3-13

ANSWERS TO EXERCISES IN SCIENTIFIC NOTATION

1) 6.51×10^{1}

2) 4.83×10^{2}

3) 1.11×10^{-2}

4) 7.61×10^{-3}

5) 8.60×10^{2}

6) 9.11×10^{-1}

7) 9.09×10^{-2}

8) 4.80×10^{0}

9) 5.62×10^{-1}

10) 6.43×10^{-2}

RESOURCE PACKAGE 3-14

THE DECIMAL POINT (MULTIPLICATION)

We are now in a position to place the decimal point through use of scientific notation.

Example #1: Solve 64.8 x 111.

Solution: First write the problem in scientific notation.

$$64.8 \times 111. = 6.48 \times 10^{1} \times 1.11 \times 10^{2}$$

Now rearrange the multipliers so they have the following order:

$6.48 \times 1.11 \times 10^{1} \times 10^{2}$ (We have grouped together the power of 10.)

But $10^{1} \times 10^{2}$ is $10 \times 100 = 1000 = 10^{3}$. Therefore our problem becomes:

$6.48 \times 1.11 \times 10^{3}$ (We added exponents to multiply them: $10^{1} \times 10^{2} = 10^{1+2} = 10^{3}$)

Then multiply 6.48 x 1.11 on the slide rule and obtain the three digits: 719. By inspection, the product of 6.48 and 1.11 has to be larger than 1 and less than 10; therefore, the decimal point in 719 has to go between 7 and 1. The final product for 64.8 x 111. is 7.19×10^{3}, which is in scientific notation. It is recommended that you leave answers in this form, unless there seems to be good reason to do otherwise. Written without powers of ten, the answer would be 7190.

Example #2: Solve .0472 x 64.2

Solution: $.0472 \times 64.2 = 4.72 \times 10^{-2} \times 6.42 \times 10^{+1}$

$$= 4.72 \times 6.42 \times 10^{-2} \times 10^{1}$$

$$= 4.72 \times 6.42 \times 1/10^{2} \times 10^{1}$$

$$= 4.72 \times 6.42 \times 1/100 \times 10$$

$$= 4.72 \times 6.42 \times 10/100$$

$$= 4.72 \times 6.42 \times 1/10$$

$$= 4.72 \times 6.42 \times 10^{-1}$$

Using the slide rule to multiply 4.72 x 6.42 yields 303. By inspection, the product of 4.72 and 6.42 is greater than 10 but less than 100. (We know this because 4 x 6 is 24 and 5 x 7 is 35.) For the decimal point to be placed in 303 such that the resulting number is greater than 10 and less than 100, the decimal point must be positioned as follows: 30.3. Therefore, the final answer for .0472 x 64.2 is 30.3×10^{-1}. This is not in best scientific form, because two digits appear to the left of the decimal point. In such cases, it is preferable to express the answer as: 3.03 (which is 3.03×10^{0} in scientific notation). Note that <u>any number with exponent zero always equals one</u>:

$$X^{0} = 1; \quad 8^{0} = 1; \quad 10^{0} = 1; \quad \left[X^{2} + 6\right]^{0} = 1; \text{ etc.}$$

RESOURCE PACKAGE 3-15

DECIMAL POINT EXERCISES (MULTIPLICATION)

Solve the following problems using the slide rule. Calculate to 3 digits and place the decimal point. Record answers in scientific notation form on notebook paper.

1) 64.2 x 1.12

2) .345 x 99.2

3) 46.2 x .212

4) .401 x 92.2

5) .00941 x 6.41

6) 33.3 x 9.21

7) .436 x .00112

8) .647 x .301

9) .00623 x .00931

10) 86.3 x .348

RESOURCE PACKAGE 3-16

ANSWERS TO DECIMAL POINT EXERCISES (MULTIPLICATION)

1) 7.19×10^{1}

2) 3.42×10^{1}

3) 9.79×10^{0}

4) 3.70×10^{1}

5) 6.03×10^{-2}

6) 3.07×10^{2}

7) 4.88×10^{-4}

8) 1.95×10^{-1}

9) 5.80×10^{-5}

10) 3.00×10^{1}

If you missed more than two problems, restudy Resource Package 3-15.

RESOURCE PACKAGE 3-17

THE DECIMAL POINT (DIVISION)

Scientific notation will also help in placing the decimal point in division.

Example: Divide 48.1 by 26.4

Solution: $\frac{48.1}{26.4} = \frac{4.81 \times 10}{2.64 \times 10} = \frac{4.81}{2.64} \times 10^{0}$

Now use the slide rule to divide 4.81 by 2.64 to obtain 182. The answer is obviously greater than 1 but less than 10. Therefore, the answer is 1.82×10^{0}.

Example #2: Divide .00621 by .0842

Solution: $\frac{.00621}{.0842} = \frac{6.21 \times 10^{-3}}{8.42 \times 10^{-2}}$

We see that 8 will not divide into 6 at least one time, so we re-write the problem as follows (The numerator is changed.):

$$\frac{62.1 \times 10^{-4}}{8.42 \times 10^{-2}}$$

$$\frac{62.1 \times 10^{-4}}{8.42 \times 10^{-2}} = \frac{62.1}{8.42} \times \frac{10^{-4}}{10^{-2}} = \frac{62.1}{8.42} \times 10^{-2}$$

Now divide 62.1 by 8.42 on the slide rule to get 738. The answer is larger than 1 but less than 10, so the decimal point is placed as follows: 7.38. Therefore, the final answer for .00621 divided by .0842 is 7.38×10^{-2}.

Expressing numbers in scientific notation will always produce an answer in scientific notation, in both multiplication and division. For division, always express the denominator with only one digit to the left of the decimal point. If the numerator does not have a number other than the denominator's first digit, make it a 2-digit number to the left of the decimal point. Inspection will then produce an answer with one and only one decimal place to the left of the decimal point.

Example: $\frac{33.4}{.0156}$ would be expressed as $\frac{3.34 \times 10^{1}}{1.56 \times 10^{-2}}$ while $\frac{.0466}{.932}$ would be expressed as $\frac{46.6 \times 10^{-3}}{9.32 \times 10^{-1}}$. The idea is to arrange the decimal point in the numerator so that the denominator will divide into the numerator at least one time, but not more than ten times. If $\frac{.0466}{.932}$ is expressed as $\frac{4.66 \times 10^{-2}}{9.32 \times 10^{-1}}$, the denominator (9.32) will not divide into 4.66 at least one time. So express the numerator with two digits to the left of the decimal, as follows: $\frac{.0466}{.932} = \frac{46.6 \times 10^{-3}}{9.32 \times 10^{-1}}$

The methods described here for locating the decimal point in multiplication and division always work; but if you have a different method which you prefer, feel free to use it. There are several schemes which work equally well.

RESOURCE PACKAGE 3-18

DECIMAL POINT EXERCISES (DIVISION)

Solve the following problems using the slide rule. Calculate to three digits, place the decimal point, and record your answers on notebook paper.

1) $\frac{6.42}{93.8}$

2) $\frac{.0123}{5.07}$

3) $\frac{.0821}{.0248}$

4) $\frac{36.2}{54.3}$

5) $\frac{291.}{.940}$

6) $\frac{86.4}{4.21}$

7) $\frac{.00333}{.148}$

8) $\frac{22.6}{.604}$

9) $\frac{.0811}{18.1}$

10) $\frac{93.2}{6.21}$

RESOURCE PACKAGE 3-19

ANSWERS TO DECIMAL POINT EXERCISES (DIVISION)

1) 6.84×10^{-2}

2) 2.43×10^{-3}

3) 3.31×10^{0}

4) 6.67×10^{-1}

5) 3.10×10^{2}

6) 2.05×10^{1}

7) 2.25×10^{-2}

8) 3.74×10^{1}

9) 4.48×10^{-3}

10) 1.50×10^{1}

RESOURCE PACKAGE 3-20

DIVISION AND MULTIPLICATION

Some problems involve both operations of division and multiplication. This procedure is easily accomplished with the slide rule, and it is with this type of problem that the slide rule begins to be a valuable time-saving device.

Example #1: Solve $\frac{346 \times .0131}{621}$

Solution: We may solve the problem more than one way. We may first multiply the numerators and then divide by the denominator. A more recommended method is to alternately divide and multiply. In this case, divide 346 by 621. Then multiply by .0131. This latter method generally produces the answer faster and requires fewer manipulations of the slide rule. The method used, however, is left entirely up to you.

$$\frac{346 \times .0131}{621} =$$

Two digits here, so that 6 can divide into 34

$$\frac{34.6 \times 10^{1} \times 1.31 \times 10^{-2}}{6.21 \times 10^{2}} =$$

Powers grouped here

$$\frac{34.6 \times 1.31 \times 10^{1} \times 10^{-2} \times 10^{-2}}{6.21} =$$

First, divide 346 by 621 and get:

$$5.57 \times 1.31 \times 10^{-3} =$$

Then multiply quotient (557) by 131. Last, add exponents and set the decimal point:

$$= 7.30 \times 10^{-3}$$

RESOURCE PACKAGE 3-21

MULTIPLICATION AND DIVISION EXERCISES

Solve the following problems to three digits. Record your answers on notebook paper and place the decimal point.

1) $\frac{24.6 \times 1.62}{.0121}$

2) $\frac{.0462 \times 3.21}{4.21}$

3) $\frac{84.5 \times 32.6}{49.1}$

4) $\frac{.0321 \times 4.62}{1.42}$

5) $\frac{861. \times 3.21}{.0421}$

6) $\frac{97.2 \times .0112}{.452}$

7) $\frac{24.4 \times 32.8}{.411}$

8) $\frac{62.3 \times .0413}{4.18}$

9) $\frac{863. \times .142}{5.41 \times .0113}$

10) $\frac{6.73 \times .0362}{4.56 \times .412}$

RESOURCE PACKAGE 3-22

ANSWERS TO MULTIPLICATION AND DIVISION EXERCISES

1) 3.29×10^{3}

2) 3.52×10^{-2}

3) 5.61×10^{1}

4) 1.04×10^{-1}

5) 6.56×10^{4}

6) 2.41×10^{0}

7) 1.95×10^{3}

8) 6.16×10^{-1}

9) 2.00×10^{3}

10) 1.30×10^{-1}

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RESOURCE PACKAGE 3-23

SELF-TEST (MULTIPLICATION AND DIVISION)

Given a time limit of thirty minutes, solve the following problems. Calculate the answers to three digits, record your answers on notebook paper, and place the decimal point.

1) (54.1) (261.)

2) (.031) (.146)

3) (67.2) (.0121)

4) (34.6) (.0014)

5) (.00311) (59.6)

6) (42.6) (.0121)

7) (.991) (.106)

8) (42.5) (92.1)

9) (.00121) (92.6)

10) (1.46) (64.1)

11) $\frac{461.}{2.86}$

12) $\frac{.0614}{29.4}$

13) $\frac{.00921}{.0121}$

14) $\frac{4.61 \times 10^2}{.0321}$

15) $\frac{9.31 \times 10^3}{.112}$

16) $\frac{9.04}{26.1}$

17) $\frac{27.7 \times 10^2}{.921}$

18) $\frac{.00142}{46.2}$

19) $\frac{43.6 \times 146.}{2.21}$

20) $\frac{.862 \times .142}{46.2}$

RESOURCE PACKAGE 3-24

ANSWERS TO SELF-TEST (MULTIPLICATION AND DIVISION)

1) 1.41×10^{4}

2) 4.53×10^{-3}

3) 8.13×10^{-1}

4) 4.84×10^{-2}

5) 1.85×10^{-1}

6) 5.15×10^{-1}

7) 1.05×10^{-1}

8) 3.91×10^{3}

9) 1.12×10^{-1}

10) 9.36×10^{1}

11) 1.61×10^{2}

12) 2.09×10^{-3}

13) 7.61×10^{-1}

14) 1.44×10^{4}

15) 8.31×10^{4}

16) 3.46×10^{-1}

17) 3.00×10^{3}

18) 3.07×10^{-5}

19) 2.88×10^{3}

20) 2.65×10^{3}

If you missed more than four (4) problems, please restudy your instructions on the use of the slide rule. Ask your teacher for assistance, if needed.

RESOURCE PACKAGE 4-1

THE SQUARE OF A NUMBER

To find the square of a number on the slide rule, we use the D and A scales. Note that the A scale is composed of two parts, such that the scale from 1 to 10 appears twice across the A scale. This reduction in size makes the A scale more difficult to read, so you must be very careful when you work with this scale.

To square a number, first express it in scientific notation with one decimal place to the left of the decimal point. Then set the number on the D scale under the hairline. The square of the number is read directly under the hairline on the A scale. Then find the square of the exponent by multiplying the power by 2.

Example #1: Square 26.1

Solution: $26.1 = 2.61 \times 10^1$

$$(26.1)^2 = (2.61 \times 10)^2$$
$$= (2.61)^2 \times (10^1)^2$$
$$= (2.61)^2 \times 10^{(1 \times 2)}$$
$$= (2.61)^2 \times 10^2$$

Now set 2.61 on the D scale and read 681 on the A scale. By inspection, the decimal point goes between the 6 and 8. Therefore, $(26.1)^2 = 6.81 \times 10^2$.

Example #2: Square .0702

Solution: $.0702 = 7.02 \times 10^{-2}$ (in scientific notation)

$$(.0702)^2 = (7.02 \times 10^{-2})^2$$
$$= (7.02)^2 \times (10^{-2})^2$$
$$= (7.02)^2 \times 10^{(-2 \times 2)}$$
$$= (7.02)^2 \times 10^{-4}$$

Now set 7.02 on the D scale and read 493 on the A scale. Since 7.02 squared is very near 49, the decimal point goes between the 9 and 3. Therefore $(.0702)^2 = 49.3 \times 10^{-4}$. This is a correct answer, but it is better expressed as 4.93×10^{-3}.

A method to use for the squaring of a number is as follows: Express the number in scientific notation with only one digit to the left of the decimal point. Set the number on the D scale and read the answer on the A scale. If the hairline falls on the left side of the A scale, the answer will have one decimal place to the left of the decimal point, (Check example #1, above). If the hairline falls on the right side of the A scale, the answer will have two decimal places to the left of the decimal point (Check example #2, above).

RESOURCE PACKAGE 4-2

EXERCISES (SQUARES OF NUMBERS)

Solve the following problems using the slide rule. Calculate to three digits, record your answers on notebook paper, and place the decimal point.

1) $(2.62)^2$

2) $(46.4)^2$

3) $(.211)^2$

4) $(.00142)^2$

5) $(.0862)^2$

6) $(.00936)^2$

7) $(1.91)^2$

8) $(892.)^2$

9) $(5.66)^2$

10) $(.911)^2$

RESOURCE PACKAGE 4-3

ANSWERS TO EXERCISES (SQUARES OF NUMBERS)

1) 6.86×10^{0}

2) 2.15×10^{3}

3) 4.45×10^{-2}

4) 2.02×10^{-6}

5) 7.43×10^{-3}

6) 8.76×10^{-5}

7) 3.65×10^{0}

8) 7.96×10^{5}

9) 3.20×10^{1}

10) 8.30×10^{-1}

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RESOURCE PACKAGE 4-4

SQUARE ROOT OF A NUMBER

To find the square root of a number, first express the number in scientific notation with one or two decimal places to the left of the decimal point, making sure that the exponent on 10 is evenly divisible by 2. If the scientific notation form has one decimal place to the left of the decimal point, set the number on the left side of the A scale and read the answer directly from the D scale. The answer will have one decimal place to the left of the decimal point.

Example #1: Find the square root of .0631.

Solution: $.0631 = 6.31 \times 10^{-2}$. Set 6.31 on the left side of scale A and read 252 on scale D.

The decimal point is placed as follows: 2.52. When you take the square root of an exponent, you divide it by 2. (This is why you were instructed to make the exponent evenly divisible by 2.) Therefore, the square root of .0631 is 2.52×10^{-1}. (Note that this exponent, -2, in 10^{-2}, is divided by 2 to get 10^{-1} in the answer.)

Example #2: Find the square root of 54.6×10^3

Solution: $54.6 \times 10^3 = 5.46 \times 10^4$ (In this form, exponent 4 divides by 2 evenly.)

$$\sqrt{5.46 \times 10^4} = \sqrt{5.46} \times \sqrt{10^4} = \sqrt{5.46} \times 10^2$$

Note that the exponent has been divided by 2.

Now, set 5.46 on the left side of the A scale and read 2.34 on D. Therefore:

$$\sqrt{5.46 \times 10^3} = \sqrt{5.46 \times 10^4} = 2.34 \times 10^2$$

If the scientific notation form has 2 places to the left of the decimal point, set the number on the right hand side of scale A and read the answer directly from D. The answer will have one place to the left of the decimal point.

Example #3: Find the square root of .456

Solution: $.456 = 45.6 \times 10^{-2}$

$$45.6 \times 10^{-2} = 45.6 \times 10^{-2} = 45.6 \times 10^{-1}$$

Set 45.6 on the right hand side of scale A and read 6.78 on the D scale. Therefore:

$$.456 = 45.6 \times 10^{-2} = 6.75 \times 10^{-1}$$

Example #4: Find the square root of 8.14×10^5

Solution: $8.14 \times 10^5 = 81.4 \times 10^4$

$$81.4 \times 10^4 = 81.4 \times 10^4 = 9.02 \times 10^2$$

By writing the number in scientific notation with the exponent evenly divisible by 2, it is always possible to have either one or two decimal places to the left of the decimal point. The number of places determines the side of scale A to be used. One digit to the left of the decimal point requires using the left side of scale A, and two digits to the left of the decimal point requires using the right side of scale A to find the square root. In this case, the answer is read directly from scale D and has one decimal place to the left of the decimal point.

The square root of 100 can be written $\sqrt{100}$ or $(100)^{\frac{1}{2}}$. Your teacher can discuss this latter notation, if you are interested.

RESOURCE PACKAGE 4-5

EXERCISES (FINDING SQUARE ROOTS)

Solve the following problems using the slide rule. Calculate to three digits, record the answers on notebook paper, and place the decimal point.

1) $\sqrt{45.1}$

2) $\sqrt{.0621}$

3) $\sqrt{862.}$

4) $\sqrt{1.62 \times 10^{1}}$

5) $\sqrt{.00542}$

6) $\sqrt{.856}$

7) $\sqrt{.0921 \times 10^{3}}$

8) $\sqrt{.000542}$

9) $\sqrt{7.67 \times 10^{3}}$

10) $\sqrt{54.6 \times 10^{1}}$

RESOURCE PACKAGE 4-6

ANSWERS TO EXERCISES (FINDING SQUARE ROOTS)

1) 6.72×10^{0}

2) 2.50×10^{-1}

3) 2.94×10^{1}

4) 4.02×10^{0}

5) 7.36×10^{-2}

6) 9.25×10^{-1}

7) 9.60×10^{0}

8) 2.33×10^{-2}

9) 8.76×10^{1}

10) 2.34×10^{1}

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RESOURCE PACKAGE 4-7

THE CUBE OF A NUMBER

To cube a number, express it in scientific notation with one decimal place to the left of the decimal point; then set the number on the D scale under the hairline and read the answer on the K scale under the hairline. Note that the K scale is divided into 3 sections from left to right. If the hairline falls on the first section, you will have one decimal place to the left of the decimal point in the answer. If the hairline falls on the second section of the K scale, the answer will have two decimal places to the left of the decimal point; and if the hairline falls on the third section of K, the answer will have three places to the left of the decimal point.

Example #1: Cube 14.1.

Solution: $(14.1)^3 =$

$$(1.41 \times 10^1)^3 = (1.41)^3 \times (10^1)^3$$
$$= (1.41)^3 \times 10^{(1)(3)}$$
$$= (1.41)^3 \times 10^3$$

Set 1.41 on D and read 280 on the K scale. Since the hairline falls on the first section of K, the answer has one decimal place to the left of the decimal point. To cube an exponent, multiply the exponent by 3. Therefore: $(24.1)^3 = (2.41 \times 10^1)^3 = (2.41)^3 \times (10^1)^3 =$

$$= 2.80 \times 10^{1x3} = 2.80 \times 10^3$$

Example #2: Cube .0304.

Solution: $(.0304)^3 = (3.04 \times 10^{-2})^3 = (3.04)^3 \times (10^{-2})^3$

$= (3.04)^3 \times 10^{(-2)(3)}$

$= (3.04)^3 \times 10^{-6}$

Set 3.04 on D and read 281 on the K scale. Since the hairline falls on the second section of K, the answer has two decimal places to the left of the decimal point. Therefore,

$$(.0304)^3 = (3.04 \times 10^{-2})^3 = 28.1 \times 10^{-6} = 2.81 \times 10^{-5}$$

Example #3: Cube 92.4×10^2.

Solution: $(92.4 \times 10^2)^3 = (9.24 \times 10^3)^3 = (9.24)^3 \times 10^{(3)(3)}$

$= (9.24)^3 \times 10^9$

Now set 9.24 on D and read 789 on K. Since the hairline falls on the third section of K, the answer has three decimal places to the left of the decimal point. Therefore,

$$(92.4 \times 10^2)^3 = (9.24 \times 10^3)^3 = 789. \times 10^9 = 7.89 \times 10^{11}$$

RESOURCE PACKAGE 4-8

EXERCISES IN CUBING

Cube the following numbers, using the slide rule. Calculate to three digits, record your answers on notebook paper, and place the decimal point.

1) $(2.44)^3$

2) $(.0112)^3$

3) $(6.42)^3$

4) $(.921)^3$

5) $(.00462)^3$

6) $(6.21 \times 10^2)^3$

7) $(.912)^3$

8) $(.00624)^3$

9) $(34.2 \times 10^2)^3$

10) $(.142 \times 10^3)^3$

RESOURCE PACKAGE 4-9

ANSWERS TO EXERCISES IN CUBING

1) 1.45×10^{1}

2) 1.41×10^{-6}

3) 2.65×10^{2}

4) 7.81×10^{-1}

5) 9.86×10^{-8}

6) 2.39×10^{8}

7) 7.59×10^{-1}

8) 2.43×10^{-7}

9) 4.00×10^{10}

10) 2.86×10^{6}

RESOURCE PACKAGE 4-10

FINDING THE CUBE ROOT OF A NUMBER

To find the cube root of a number, first express the number in scientific notation with one, two, or three decimal places to the left of the decimal point and such that the exponent on 10 is evenly divisible by 3. If the resulting expression has one decimal place to the left of the decimal point, set the number on the first section of the K scale and read the answer on D. If the expression has two decimal places to the left of the decimal point, set the number on the second section of K and read the answer on D. If the expression has three decimal places to the left of the decimal point, set the number on the third section of K and read the answer on D. In all three cases, the answer will have one decimal place to the left of the decimal point. To find the cube root of the exponent on 10, divide it by 3.

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Example: Find the cube root of 3,410.

Solution: $3{,}410 = 3.41 \times 10^3$

$$\sqrt[3]{3{,}410} = \sqrt[3]{3.41 \times 10^3} = \sqrt[3]{3.41 \times {}^3\ 10^3}$$

$$= {}^3\ 3.41 \times 10^1$$

Note that $\sqrt[3]{3{,}410}$ could also be written $(3{,}410)^{1/3}$.

Set 3.41 on the first section of K and read 151 on D. Therefore:

$$\sqrt[3]{3{,}410} = 1.51 \times 10^1$$

Example #2: Find the cube root of .0842.

Solution: $.0842 = 84.2 \times 10^{-3}$

$$\sqrt[3]{.0842} = \sqrt[3]{84.2 \times 10^{-3}} = \sqrt[3]{84.2 \times 10^{-1}}$$

Set 84.2 on the second section of K and read 4.40 on D. Therefore:

$$\sqrt[3]{.0842} = 4.40 \times 10^{-1}$$

Example #3: Find the cube root of 56.2×10^{7}

Solution: $56.2 \times 10^{7} = 562. \times 10^{6}$

$$\sqrt[3]{562. \times 10^{6}} = \sqrt[3]{562. \times 10^{2}}$$

Set 562 on the third section of K and read 830 on D. Therefore:

$$\sqrt[3]{56.2 \times 10^{7}} = 8.30 \times 10^{2}$$

The cube root of 1,000 can be written as $\sqrt[3]{1,000}$ or $(1,000)^{1/3}$.

Your teacher can discuss this with you, if you are interested.

RESOURCE PACKAGE 4-11

EXERCISES IN FINDING CUBE ROOTS

Solve for the following cube roots using the slide rule. Calculate to three places, record your answers on notebook paper, and place the decimal point.

1) $\sqrt[3]{.0462}$

2) $\sqrt[3]{39.2}$

3) $\sqrt[3]{3.11 \times 10^4}$

4) $\sqrt[3]{.0156}$

5) $\sqrt[3]{34.1 \times 10^4}$

6) $\sqrt[3]{562.}$

7) $\sqrt[3]{.00921}$

8) $\sqrt[3]{85.6 \times 10^5}$

9) $\sqrt[3]{.0411 \times 10^2}$

10) $\sqrt[3]{.624 \times 10^5}$

RESOURCE PACKAGE 4-12

ANSWERS FOR EXERCISES WITH CUBE ROOTS

1) 3.60×10^{-1}

2) 3.40×10^{0}

3) 3.14×10^{1}

4) 2.50×10^{-1}

5) 7.02×10^{1}

6) 8.25×10^{0}

7) 2.10×10^{-1}

8) 2.05×10^{2}

9) 1.60×10^{0}

10) 3.97×10^{1}

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RESOURCE PACKAGE 4-13

SELF-TEST (SLIDE RULE)

Given a time limit of thirty minutes, solve the following problems. Calculate answers to three decimal places, record your answers on notebook paper, and place the decimal point.

1) $(2.45)^2$

2) $(.00142)^2$

3) $\sqrt{.0112}$

4) $\sqrt{34.1}$

5) $\sqrt{.932}$

6) $(56.1 \times 10^2)^2$

7) $(.0921)^2$

8) $\sqrt{.0946}$

9) $(2.46)\ (\sqrt{34.6})$

10) $(93.6)^2\ \ (1.92)$

11) $(.341)^3$

12) $\sqrt[3]{92.1}$

13) $(10.4)^3$

14) $\sqrt[3]{.00341}$

15) $(.00421)^3$

16) $(2.46)\ \sqrt[3]{1.21}$

17) $(36.2)^2\ \ (.0121)^3$

18) $\sqrt[3]{.00411}$

19) $(62.1)^2$

20) $\dfrac{\sqrt{246}}{(21.4)}$

ANSWERS TO SELF TEST (SLIDE RULE)

1) 6.00×10^{2}

2) 2.02×10^{-6}

3) 1.06×10^{-1}

4) 5.84×10^{0}

5) 9.65×10^{-1}

6) 3.15×10^{7}

7) 8.48×10^{-3}

8) 3.08×10^{-1}

9) 1.45×10^{1}

10) 1.68×10^{4}

11) 3.97×10^{-2}

12) 4.52×10^{0}

13) 1.12×10^{3}

14) 1.51×10^{-1}

15) 7.46×10^{-8}

16) 2.62

17) 2.32×10^{-3}

18) 1.61×10^{-1}

19) 3.86×10^{3}

20) 7.33×10^{-1}

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